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FINAL REPORT

Astrophysical Studies
NAGW-1973

Covering the Period
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Final Report for NASA Grant "Astrophysical Studies"

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Princeton University

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Personnel

This grant supported research in theoretical studies of the interstellar medium. Since 1989, this grant supported the following postdoctoral researchers:

Dr. Frank Bertoldi (Oct. 1989 – Aug. 1992)

Dr. Emma Bakes (Oct. 1992 – Aug. 1995)

Scientific Research

Research was carried out in the following areas:

i. Structure of Molecular Clouds

Bertoldi (in collaboration with C.F. McKee) investigated the structure of molecular clouds. Bertoldi & McKee (1992) conclude that many of the clumps in molecular clouds are actually pressure-confined. Only the more massive clumps are self-gravitating; the most massive of these are "magnetically supercritical" (i.e., cannot be supported by magnetic pressure alone) and require generation of internal turbulence to support them.

ii. Structure of HII Regions

Bertoldi (in collaboration with E.B. Jenkins) investigated the implications of IMAPS ultraviolet observations of absorption toward πSco by NII ions in the excited fine structure levels. The observed absorption indicates surprisingly high pressure in the region where the excited NII is located. Bertoldi and Jenkins (1992) concluded that this high-pressure "clump" is probably a photoevaporating outflow from a protoplanetary disk around a low mass star. They argued that there are likely to be large numbers of such systems in the neighborhood of πSco, presumably a gravitationally bound star cluster of which πSco is the only bright member. Until the IMAPS spectra were available the πSco HII region appeared to be an ordinary HII region around a middle-aged B1V + B2V binary far from its natal molecular cloud. If an "ordinary" binary like πSco has an associated cluster of low-mass stars with disks, then this must presumably be a common phenomenon! The Bertoldi & Jenkins hypothesis – while seemingly radical – may in fact be the *least* unorthodox explanation for the observations! Observations to test the hypothesis were proposed; it is hoped that they will be carried out in the near future.

iii. PAH Molecules: Charging and Photoelectric Heating

Bakes & Tielens (1994ab) studied the charging of PAH molecules by photoelectric emission and collisions with electrons, and evaluated the heating of the interstellar gas due to the photoelectric emission. They concluded that if PAHs are present in the ISM with the abundances required to explain the UIR emission bands, then the photoelectric heating

by PAHs should be the dominant heating process in diffuse clouds and in photodissociation regions.

The resulting rates of photoelectric heating by PAHs and small grains were used to study the thermal equilibrium of gas in photodissociation fronts illuminated by cool stars (Spaans *et al.* 1994), and the thermal equilibrium of interstellar gas (Wolfire *et al.* 1995).

Bakes & Tielens (1995) recently reexamined PAH charging processes, and confirmed that in diffuse regions, including photodissociation fronts, a substantial fraction of PAHs should be neutral.

Together with Snow, Buss, and Seab, Bakes discussed the implications which the observed relative weakness of diffuse bands in nebular environment may have on the hypothesis that the diffuse bands are produced by PAH^+ ions (Snow *et al.* 1995). Because of the expected rapid recombination rates for PAH^+ ions, it is not clear in what environment the PAHs would be expected to be in predominantly cation form.

Publications supported by NAGW-1973 during the period 1990-1995

This includes 2 papers (Draine & Woods 1991, 1992) reporting work carried out by Dr. D. Tod Woods, who was supported by this grant during the period Jan. 1987 – Aug. 1989:

Bakes, E.L.O., & Tielens, A.G.G.M. 1994a, "The Photoelectric Heating mechanism for Very Small Graphitic Grains and Polycyclic Aromatic Hydrocarbons", *Ap. J.*, **427**, 822

Bakes, E.L.O., & Tielens, A.G.G.M. 1994b, "Photoelectric Heating of Interstellar Gas by PAHs and Small Graphitic Grains", in *The First Symposium on the Infrared Cirrus and Diffuse Interstellar Clouds*, ed. R. Cutri and W. Latter, 412.

Bakes, E.L.O., & Tielens, A.G.G.M. 1995, "Charge Variation of Polycyclic Aromatic Hydrocarbons in the Diffuse Interstellar Medium", in *The Diffuse Interstellar Bands*, ed. A.G.G.M. Tielens & T.P. Snow (Dordrecht: Kluwer), 315.

Bertoldi, F. & Jenkins, E.B. 1992, "Dense Clumps of Ionized Gas Near π Scorpii, as Revealed by the Fine-Structure Excitation of N II", *Ap. J.*, **388**, 495.

Bertoldi, F. & McKee, C.F. 1992, "Pressure-Confined Clumps in Magnetized Molecular Clouds", *Ap. J.*, **395**, 140.

Draine, B.T., & Woods, D.T. 1990, "On the H_2 Line Emission from NGC 6240 and other Starburst Galaxies", *Ap. J.*, **363**, 464

Draine, B.T., & Woods, D.T. 1991, "Supernova Remnants in Dense Clouds. I. Blast-Wave Dynamics and X-Ray Irradiation", *Ap. J.*, 383, 621.

Snow, T.P., Bakes, E.L.O., Busss, R.H., & Seab, C.G. 1995, "The weakness of diffuse bands in nebular environments: Possible impact on the PAH^+ hypothesis", *Astr. Ap.*, **296**, L37.

Spaans, M., Tielens, A.G.G.M., van Dishoeck, E.F., & Bakes, E.L.O. 1994, "Photon-dominated Regions around Cool Stars: The Effects of the Color Temperature of the Radiation Field", *Ap. J.*, **437**, 270.

Wolfire, M.G., Hollenbach, D., McKee, C.F., Tielens, A.G.G.M., & Bakes, E.L.O. 1995, *Ap. J.*, **443**, 152.